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Research Article

Comparison of Diagnostic Accuracy of Ultrasound and Finger Palpation for Endotracheal Tube Placement Confirmation in Children: A Clinical Trial

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ABSTRACT

Background: Accurate confirmation of endotracheal tube (ETT) placement is essential to ensure adequate ventilation and prevent life-threatening complications in pediatric anesthesia. Traditional methods such as auscultation and capnography have inherent limitations. Point-of-care ultrasound (POCUS) has recently emerged as a rapid and reliable alternative. This study aimed to compare the diagnostic accuracy of ultrasound and finger palpation for ETT placement confirmation in children undergoing general anesthesia.

Methods: In this diagnostic accuracy clinical trial, 60 children aged 3–6 years (ASA I–II) scheduled for elective surgery were enrolled. Following standardized tracheal intubation, both ultrasound and finger palpation were performed sequentially by independent blinded operators. Fiberoptic bronchoscopy served as the reference standard. Diagnostic indices, including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), were calculated. Secondary outcomes included operator confidence (5-point Likert scale) and time to confirmation.

Results: Ultrasound achieved higher sensitivity (92.5%) and specificity (71.4%) compared with finger palpation (79.2% and 100%, respectively). The PPV and NPV for ultrasound were 96.1% and 55.6%, whereas those for palpation were 100% and 38.9%. Operator confidence was significantly greater with ultrasound (4.37 ± 0.74) than with palpation (3.45 ± 1.03; $p < 0.001$). The mean confirmation time was also shorter using ultrasound (16.12 ± 1.55 s) than palpation (20.95 ± 1.88 s; $p < 0.001$). No complications occurred.

Conclusion: Tracheal ultrasonography provides a rapid, highly sensitive, and non-invasive way of verifying the proper placement of the endotracheal tube (ETT) in children, which is much more accurate and rapid than finger palpation. While finger palpation is a simple bedside technique with an ideal specificity, its low sensitivity makes it less useful as a sole diagnostic tool. The incorporation of ultrasonography into the usual management of the pediatric airway may have the potential of enhancing patient safety.

The authors declare no conflicts of interest.
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Introduction

To ensure effective ventilation and prevent potentially lethal outcomes such as aspiration, endobronchial intubation, and inadvertent extubation, accurate verification of the endotracheal tube (ETT) position is essential [1].Each of the conventional confirmation techniques, such as chest radiography, auscultation, and capnography, has important drawbacks [2]. Auscultation cannot pinpoint the precise location of the tube tip in relation to the carina and may not be accurate in noisy situations [3].

Despite its excellent sensitivity in identifying esophageal misplacement, capnography can produce false-negative results in situations involving tissue hypoperfusion or cardiac arrest [4]. Chest radiography, considered the gold standard for establishing tube depth, is linked with radiation exposure, longer turnaround times, and limited availability in emergency or resource-restricted settings [5]. As a result, quick, precise, and noninvasive bedside techniques to verify ETT location are becoming more and more necessary [6]. Real-time tracheal ultrasonography is an accurate method for identifying endotracheal tube position during CPR without the need for interruption of chest compression [7]. Recent observational and prospective randomized studies have shown that tracheal ultrasonography has a good sensitivity and specificity for detecting proper tracheal intubation [8]. Sarode and colleagues demonstrated in a multicenter randomized research that sonographic viewing of the ETT cuff offers trustworthy confirmation of placement, and that there is no discernible difference in the rate of repositioning following radiographic verification as compared to conventional methods [9]. According to Maski and colleagues, ultrasound verified tube location more quickly than waveform capnography (mean 16.36 seconds) while preserving similar levels of specificity (90.91%), sensitivity (97.62%), and accuracy (96.84%) [10]. Transtracheal ultrasonography has recently proven to be a quick bedside tool and has shown excellent diagnostic accuracy in adult patients [3]. Despite mounting evidence in favor of ultrasonography, issues with operator proficiency, probe accessibility, and the requirement for systematic training have hindered its uptake [7]. Moreover, most studies have evaluated ultrasound in comparison with capnography or radiography, whereas fewer investigations have directly compared ultrasound with fingertip palpation—a technique in which the clinician palpates the subglottic region to feel the ETT cuff as it contacts the cricoid cartilage [1]. Fingertip palpation is simple, requires no additional equipment, and can be performed immediately after intubation; however, its diagnostic performance in older children and adults has not yet been fully investigated [1]. Therefore, given the lack of evidence regarding the accuracy of this method in children, the present study was conducted to evaluate the diagnostic value of ultrasound and tracheal palpation, using ultrasound and fiberoptic bronchoscopy as reference standards, in determining ETT position in pediatric patients undergoing surgery under general anesthesia.

Methods

Study Design and Ethical Considerations

This single-group diagnostic accuracy clinical trial was performed at Imam Hossein Hospital in Isfahan, Iran. The study aimed to evaluate the diagnostic efficacy of ultrasound and digital (finger) palpation in verifying the position of the endotracheal tube (ETT) in pediatric patients. The Iranian Registry of Clinical Trials (IRCT20160307026950N62) and the Ethics Committee of Isfahan University of Medical Sciences (Approval Code: IR.MUI.MED.REC.1402.382) both approved the protocol. The study adhered to the ethical guidelines outlined in the Declaration of Helsinki and was reported in accordance with the CONSORT 2010 statement [11].

Participants

Children between the ages of 3 and 6 years, who were scheduled for elective surgery under general anesthesia, were recruited using straightforward consecutive sampling. Inclusion criteria consisted of written informed consent from parents or legal guardians, ASA physical status I–II, and the absence of airway malformations or active respiratory disease. Exclusion criteria encompassed challenging airway, congenital anomalies of the head or neck, or retraction of consent. Patients who underwent failed or challenging intubation were omitted from the final analysis.

Managing anesthesia and putting in a tube

Anesthetic Management and Intubation Procedure

All patients received standardized general anesthesia. An attending anesthesiologist used appropriately sized cuffed ETTs (Supa, Iran) to perform tracheal intubation after induction. Following a successful intubation, independent operators blind to one another's results consecutively carried out the verification procedures of finger palpation and ultrasound. The researcher palpated the trachea by lightly pressing the suprasternal notch with the non-dominant hand's index finger, then gradually retracted the ETT until the cuff was felt passing beneath the finger. The tube was then advanced 5 mm and fixed at that level. We used a high-frequency linear probe (6–13 MHz) to confirm the ultrasound. We placed the probe across the suprasternal notch and moved it cranially toward the thyroid cartilage while the patient tilted their head back slightly.

The operator visualized real-time entry of the ETT through the tracheal rings. Sonographic signs used for confirmation included the *snowstorm sign* (echogenic turbulence of air), *bullet sign* (opening of vocal cords with acoustic shadow of the ETT), and absence of a *double-tract sign* (parallel air–mucosa lines indicating esophageal intubation). If esophageal placement was suspected, the anesthesiologist was immediately informed for correction.

Reference Standard

Fiberoptic bronchoscopy was used as the reference (gold standard) for definitive confirmation of tube position after both assessment techniques were completed.

Outcome Measures

The main goal was to find out how accurate ultrasound and finger palpation were as tests, using sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) in relation to fiberoptic bronchoscopy results.

The secondary outcomes included:

1. **Time to confirmation** – measured in seconds from initiation of assessment to final confirmation using a stopwatch by an independent observer.
2. **Operator confidence** – rated immediately after each evaluation using a 5-point Likert scale (1 = not confident at all, 5 = very confident).

Sample Size

Sample size was calculated based on a diagnostic accuracy formula with a 95% confidence level and 10% margin of error, resulting in a minimum of 60 participants. Considering potential dropouts, recruitment continued until this number was achieved.

Statistical Analysis

All analyses were performed using SPSS software version 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics (mean ± SD and frequency %) were used for demographic and diagnostic variables. Sensitivity, specificity, PPV, and NPV were computed for each method. Comparison of time and confidence scores between techniques was performed using the paired t-test or Wilcoxon signed-rank test as appropriate. A P value < 0.05 was considered statistically significant.

Results

A total of 60 pediatric patients aged 3 to 6 years completed the study protocol. No patient was excluded due to failed or difficult intubation.

Baseline demographic characteristics of the study population are presented in Table 1. The mean age of participants was 4.7 ± 1.1 years. Of the enrolled children, 39 (65.0%) were female and 21 (35.0%) were male. All patients were classified as ASA physical status I or II (Table 1).

Diagnostic Accuracy

The 2×2 confusion matrices comparing each diagnostic method with the fiberoptic bronchoscopy reference standard are shown in Table 2. Ultrasound correctly identified 49 true positives, 5 true negatives, 4 false negatives, and 2 false positives. In contrast, finger palpation identified 42 true positives, 7 true negatives, 11 false negatives, and no false positives (Table 2).

Based on these results, the calculated diagnostic indices are presented in Table 3. Ultrasound demonstrated higher sensitivity (92.5%, 95% CI 82.1–97.0) compared with finger palpation (79.2%, 95% CI 66.5–88.0). The specificity of ultrasound was 71.4% (95% CI 35.9–91.8), whereas finger palpation achieved 100% specificity (95% CI 64.6–100.0). The positive predictive value (PPV) and negative predictive value (NPV) for ultrasound were 96.1% (95% CI 86.8–98.9) and 55.6% (95% CI 26.7–81.1), respectively. For finger palpation, the PPV was 100% (95% CI 91.6–100.0) and the NPV was 38.9% (95% CI 20.3–61.4). Overall, ultrasound demonstrated greater diagnostic sensitivity and overall accuracy, while palpation showed perfect specificity but lower sensitivity (Table 3).

Secondary Outcomes

Secondary outcomes are summarized in Table 4. The mean investigator confidence score on the 5-point Likert scale was significantly higher for ultrasound (4.37 ± 0.74) than for finger palpation (3.45 ± 1.03) ($p < 0.001$, Wilcoxon signed-rank test). The mean confirmation time was also significantly shorter with ultrasound (16.12 ± 1.55 seconds) compared with finger palpation (20.95 ± 1.88 seconds) ($p < 0.001$, paired t-test). No complications, such as airway trauma, hypoxia, or esophageal intubation, were observed during the study (Table 4).

Table 1- Baseline Characteristics of the Study Population (N = 60)

Variable	Value	Notes
Age, years (Mean ± SD)	4.7 ± 1.1	As recorded at enrollment
Sex, Female n (%)	39 (65.0)	Remaining male: 21 (35.0)
ASA physical status, I/II – n (%)	—	All ASA I or II

Table 2- 2×2 Confusion Matrices Against Fiberoptic Bronchoscopy (Reference Standard)

Method	TP	FP	TN	FN
Ultrasound	49	2	5	4
Finger palpation	42	0	7	11

Abbreviations: TP = true positive; FP = false positive; TN = true negative; FN = false negative.

Table 3- Diagnostic Accuracy with 95% Confidence Intervals

Method	Sensitivity % (95% CI)	Specificity % (95% CI)	PPV % (95% CI)	NPV % (95% CI)
Ultrasound	92.5 (82.1–97.0)	71.4 (35.9–91.8)	96.1 (86.8–98.9)	55.6 (26.7–81.1)
Finger palpation	79.2 (66.5–88.0)	100.0 (64.6–100.0)	100.0 (91.6–100.0)	38.9 (20.3–61.4)

All indices were calculated using fiberoptic bronchoscopy as the reference. 95% CIs are Wilson score intervals.

Table 4- Comparison of Investigator Confidence and Confirmation Time

Variable	Ultrasound (Mean ± SD)	Finger Palpation (Mean ± SD)	P value
Investigator confidence score (1–5 Likert)	4.37 ± 0.74	3.45 ± 1.03	< 0.001 †
Confirmation time (seconds)	16.12 ± 1.55	20.95 ± 1.88	< 0.001 ‡

† Wilcoxon signed-rank test (non-parametric). ‡ Paired t-test (parametric).

Discussion

In the present study, two methods—point-of-care ultrasound and tracheal palpation with a finger—were compared for confirming the endotracheal tube (ETT) position in children aged 3–6 years.

The results showed that tracheal ultrasound, while maintaining very high sensitivity (92.5%) for detecting the correct position of the tube tip, required a significantly shorter confirmation time (16.12 seconds) compared to the palpation method.

The operators also felt more confident when using ultrasound (mean confidence score 4.37 vs. 3.45).

Although tracheal fingertip palpation had complete specificity (100%) and a positive predictive value (100%), it had lower sensitivity (79.2%) and thus a relatively higher rate of false-negative results.

In other words, if palpation indicates that the tube does not contact the carina, this is almost always correct, but in cases where the tube has advanced too deeply, palpation may be misleading.

These findings suggest that tracheal ultrasound, in addition to offering greater speed and certainty in confirming correct tube placement, provides high sensitivity for identifying proper intubation, whereas simple fingertip palpation, despite its simplicity and equipment-free nature, offers high specificity for confirming correct intubation, but its sensitivity decreases in older children. The findings of this study are consistent with previous results regarding the role of ultrasound in confirming endotracheal tube placement. Several studies have reported the high accuracy of ultrasound. For example, a study in Maskay demonstrated that both point-of-care ultrasound and capnography are reliable methods for confirming correct ETT placement, but ultrasound reduces confirmation time [10].

According to a recent systematic analysis of pediatric studies conducted by Liu et al. (2023), the diagnostic accuracy of ultrasound for verifying tracheal intubation ranged from 90.6% to 100% [12]. Uya et al. (2020), in a study on children, showed that ultrasound evaluation of cuff position at the xiphoid region had 95% agreement with radiography, with similarly high accuracy (sensitivity 96%) [13]. A three-point combination of anterior neck and bilateral chest ultrasound successfully detected 97.4% of cases (sensitivity 98%), according to Gautam et al. (2025), who studied children ages 3 to 12 [14]. Additionally, Wani et al. (2021) assessed the ETT cuff in children using ultrasonography and found that, in comparison to radiography, it is a quick and efficient method that provides accurate cuff localization [15].

In a pediatric intensive care unit, Chandanani et al. (2021) discovered that point-of-care ultrasound had a 97.8% accuracy rate and a 97.7% sensitivity for tube confirmation [16]. Additionally, according to a recent thorough assessment in neonates [17], ultrasound confirmed accurate intubation in 96.8% of instances with a pooled sensitivity of 93.44%; additionally, the ultrasound confirmation time was noticeably less than that of a chest X-ray.

However, prior research has also demonstrated that tracheal fingertip palpation is a rapid and easy way to determine a child's proper ETT depth. [18].

All things considered, this body of research demonstrates that ultrasound is a quick, accurate, and secure method of verifying ETT insertion.

However, prior research has also demonstrated that tracheal fingertip palpation is a rapid and easy way to determine the proper ETT depth in infants.

Masoumi et al. (2022), for instance, found that while auscultation and palpation both showed a moderate correlation with the reference method, palpation was marginally superior [18].

In another study, Moll et al. found that palpation determined the more appropriate tube position [19].

Our findings are in agreement with these studies in one aspect: fingertip palpation shows relatively good sensitivity and is highly reliable when it indicates incorrect tube placement. However, unlike many studies, we found that sensitivity of palpation decreases in older children; this is probably due to thicker tissue or anatomical changes of the neck with increasing age.

In other words, palpation is only reliable when the tube has not been inserted too deeply.

Additionally, tracheal ultrasound in adults has good sensitivity and specificity (96% and 88%), according to studies like Zamani-Moghadam (2017), suggesting that the diagnostic principles of ultrasound are not restricted to any particular age group [20].

In their study of PICU patients, Guerder et al. (2021) found that pleural ultrasound (lung sliding evaluation) shortened the confirmation time from 10 to 2 minutes, but its sensitivity was only 77%. They came to the conclusion that although this method is quick, it might not be appropriate for determining precise depth unless done by a skilled operator [21]. This emphasizes that in order to increase accuracy, proper training and standardization of ultrasound procedures are required. In general, previous research indicates that airway ultrasound offers unique advantages for confirming tracheal intubation in children: high accuracy, rapid results, and no radiation exposure.

Therefore, it has been recommended that ultrasound be used as a complementary tool alongside reference methods (clinical tests, capnography, and imaging).

In contrast, although fingertip palpation is simple and inexpensive, in our study its performance was more limited in children over 3 years old. This finding aligns with studies by Yoo et al. (2007) [22] and Masoumi et al. [18], both emphasizing the importance of combining multiple methods to improve diagnostic precision. Nevertheless, this study was not without limitations. Its relatively small sample size (60 children), single-center design, and nonrandom sampling could affect the validity of the results and limit generalizability. The study included only healthy children (ASA I–II), and patients with airway anomalies or cardiopulmonary disorders were excluded. Therefore, extrapolation of the findings to sick or emergency pediatric populations should be done with caution. It is advised that systematic teaching programs be created for anesthesiologists and critical care experts addressing airway ultrasound techniques in order to improve operator abilities in quickly diagnosing tube position, based on the results of this study and prior research. To improve dependability, further research should be done on the adoption of established methods (such the three-point or combination techniques) for intubation confirmation.

In special situations—such as emergencies or patients at high risk of tube displacement or mainstem intubation—ultrasound should be employed alongside other rapid diagnostic methods such as capnography or clinical signs. Future studies should include broader age groups (including neonates and older children) and emergency cases, adopt multicenter randomized designs, and compare ultrasound performance directly with different methods such as chest radiography and capnography. In addition, further research is warranted on effective training methods and the learning curve of tracheal ultrasound.

Finally, our findings demonstrate that tracheal ultrasound in children aged 3 to 6 years is a rapid method with very high sensitivity for confirming correct endotracheal tube placement, with significantly shorter confirmation time compared with palpation.

While fingertip palpation is also an equipment-free and relatively sensitive method for identifying correct tube position (with perfect PPV), its lower sensitivity in older children limits its standalone application.

Conclusion

Together with previous evidence, our results indicate that using ultrasound as a complementary tool alongside reference methods can improve confirmation of ETT placement. At the same time, further studies are needed to validate its effectiveness across diverse populations and clinical scenarios. With broader training and the establishment of standardized protocols, tracheal ultrasound could become an effective and safe method for enhancing airway management safety in pediatric intubation.

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